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FURTHER STUDIES ON BROWN HEART IN SWEDES[1]

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During the past thirteen years at Macdonald College, a number of investigations relating to boron deficiency in the swede have been carried out in co-operation between the Departments of Agronomy and Plant Pathology. This work has centred largely around the production of swedes in the field, where the incidence of disease and the efficiency of various control measures were studied. The agronomic aspects of the problem were supplemented by greenhouse experiments and a brief resumé of some of these results was published by Coulson and Raymond (8) in 1937.

The object of this report is to consolidate these studies, and to present data from limited trials carried out to determine the influence of potassium and calcium on brown heart development and the role of boron deficiency in seed production.

REVIEW OF LITERATURE

Brown heart in swedes (*Brassica napus* L. var. *napobrassica* (L.) Reichb.) was first mentioned in Canada by the Dominion Botanist (11) in 1910, and in 1933 MacLeod and Howatt (25) found that it could be controlled by adding boron to the soil. Their work has been substantiated by a number of investigators (8, 32, 40, 46) who have established the fact that brown heart is a physiological disease resulting from an insufficient supply of boron.

Brown heart is known under a number of names. In Scotland it is called "raan" (33), while in Ontario it is commonly referred to as "water core" (24). The terms "dark centre" (40), "woody centre," "water heart", "black heart", and "punky core", have also been used at various times (19).

While a deficiency of boron is characterized in most plant species by death of the growing point (28, 31), this symptom is only observed in swedes suffering from the severe deficiencies obtained under controlled conditions (9, 18). In the field the growing point remains alive and the symptoms are concentrated mainly in the bulbous root, which necessitates cutting to determine the presence or absence of visible symptoms (8, 10, 32, 40). Several authors (3, 4, 8) have associated severe brown heart with roots possessing a scurfy surface.

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The disease appears as definite brownish or water soaked areas occurring at irregular intervals in the parenchyma (32), and the diseased tissue generally does not extend outwards as far as the cambium (8, 19, 40). These areas may be small and scattered or arranged in definite groups. Distinctive patterns have been observed to characterize certain swede strains (9). Usually the discoloured areas are more pronounced in the lower half of the storage root (2, 32) and extend upward beyond the shoulder to the neck only in severe cases (10). In storage these areas become grey and punky, but do not increase or decrease in number and extent (8, 19).

The symptoms developed by swedes grown in sand cultures with a limited supply of boron are adequately described by Hill and Grant (18), and Coulson and Raymond (8). Where no boron is supplied to the media, these workers found that the plants soon die.

Borax (sodium tetraborate) applied either as a powder to the soil or a spray to the foliage is the most efficient way of supplying boron and controlling the disease (6, 8, 24, 26), the method and amount depending on the soil type. Broadcast applications varying from 10 to 50 pounds per acre are generally recommended in Canada, Great Britain, New Zealand and the United States (1, 9, 23, 33, 47).

MATERIALS AND METHODS

(1) Field Trials

Swede varieties were grown in randomized blocks replicated at least four times with the plants thinned to a distance of one foot in either one or two row plots. The usual size of plot was sixty-six feet long with the rows thirty inches apart. Random samples of from twenty-five to seventy-five roots were taken from each variety in each replication.

Swedes were normally planted in the middle of May and sampled in the fall. The roots were cut, their diameters measured, and the percentage and degree of brown heart recorded. The degree of brown heart was determined by comparing the pattern of disease to a scale ranging from zero to ten, and the average degree for a variety was calculated as follows. The number of roots with a given degree was multiplied by this degree and the sum of number x degree divided by the total number of diseased roots. The average degrees calculated for each replicate were then added and divided by the number of replications to give the average degree of a variety.

For the purpose of studying the effect of environmental conditions and plant vigour[1] in relation to brown heart development, a very complete picture of the prevalence of boron deficiency was available from data obtained in the years 1933 to 1944, inclusive. Observations were only considered from trials that did not receive borax. Thus for the eleven years in question this phase of the work was based upon percentages of brown heart determined from a total of 15,895 roots, with a minimum of 875 in any one year.

To measure the effect of keeping the soil moist, three replications of four swede varieties were divided down the centre, and one-half of the range supplied with water through irrigation pipes.

[1] Root size as measured by diameter through widest portion of the root was taken as a criterion of plant vigour.

The course of brown heart development was followed by examining samples taken from several varieties at one- or two-week intervals, starting when the roots were beginning to size.

Borax spray schedules were based upon root size (after MacLachlan (24)) with plants receiving the first spray when their roots were 1-1½ inches in diameter. Thus a two-week spray would consist of a single application two weeks after the roots had reached the 1-1½ inch stage. The same holds true for the monthly spray. Split-sprays consisted of an application of borax at the 1-1½ inch stage and another one month later if there was evidence of brown heart in the check plots at this time. In the two trials reported both applications of the split-spray were used.

All sprays were applied at two concentrations (8 and 16 pounds of borax in 40 gallons of water plus sufficient soap solution to give adequate coverage) with the exception of the split-spray where both treatments were at the eight-pound level.

The soils on which the experiments were conducted approach neutrality and range in texture from sandy loam to clay.

(2) Nutrition Studies

Swedes were grown to maturity in high grade quartz sand in order to investigate various aspects of boron nutrition. One-gallon glazed crocks provided with two drainage holes were used for this purpose.

The basic nutrient solution supplied the following elements in parts per million: N—168; P—77; N—78; Ca—100; Mg—61; S—122; plus a supplementary solution supplying traces of Fe, Mn and Zn.

Plants were fed at weekly intervals and all crocks were flushed with one litre of distilled water the day before feeding. Tap-water allowed for the production of deficiency symptoms comparable to those obtained with distilled water.

These methods were employed also for the study of mature roots selected for seed production.

For the purpose of growing swedes outdoors, 2½ gallon crocks were set in the ground with two inches above the soil line. The gallon crocks were then placed within these larger containers and raised flush with the top by the use of wooden blocks. Bare ground between the crocks was covered with a mulch of grass clippings.

Observations expressed as percentages were transformed when necessary (7) before being subjected to the analysis of variance (16).

ENVIRONMENT AND PLANT VIGOUR

Warington (43) and Eaton (15) have reported that boron deficiencies are less pronounced under the short day conditions of spring and autumn. The amount of growth was also considered by Eaton who found that deficiency symptoms developed to a greater degree when the plants in question were growing vigorously. McMurtrey (28) and Wilcox (49) have also observed a positive correlation between injury and the vigour of tobacco plants and apple trees, respectively, while Schropp and Arenz (37) found the effect of boron deficiency on the nitrogen metabolism of cotton plants to depend largely on their growth intensity.

A number of investigators (30, 36, 42, 51) have associated an increase in moisture supply with a reduction in boron deficiency. On the other hand, the moisture content of the soil does not seem to influence the black spot disease of garden beets, because at times the disease is more severe on the drier parts of one field and the wetter parts of another (45). In a recent publication, Eaton (14) suggests that the apparent relationship that exists between moisture supply and boron deficiency is more truly one between average light intensity and boron deficiency. There was no evidence that drying reduced the boron concentration in the soil solution when no new boron was added.

In an effort to explain at least a portion of the extreme variation encountered in the study of this disease a number of correlation analyses were carried out between brown heart, plant vigour, rainfall, sunshine and temperature. Furthermore, to test the reaction of additional moisture over and above the normal precipitation, an experiment was conducted wherein the moisture content of the soil was increased through irrigation.

Results

From the preliminary analysis a conspicuous relation was observed between average percentage brown heart, and hours of sunshine and inches of rainfall, while mean monthly temperatures were of little importance. The close association for the first two factors with the percentage brown heart only manifested itself, however, in the later part of the growing season, with the strongest correlation being found for the months of August and September.

Therefore, the gross correlation coefficients were calculated for all interrelationships between average percentage brown heart, average plant vigour (root size), hours of sunshine for August and September, and inches of rainfall for these two months (Table 1). The positive correlation found for brown heart and rainfall is significant at the five per cent point, as are the negative correlations between brown heart and sunshine, and plant vigour and sunshine.

Table 1.—Gross correlation coefficients

	1 Brown heart	2 Plant vigour	3 Sunshine
2. Plant vigour	+.4832		
3. Sunshine (hours for Aug. and Sept.)	−.6952*	−.7077*	
4. Rainfall (inches for Aug. and Sept.)	+.6547*	+.0337	−.4834

There was considerable interrelationship between the independent variables as shown by the partial correlation coefficients, since when two of the factors were held constant the correlation decreased in all cases. The most persistent relationship was found between brown heart and rainfall: $r_{14.2} = +.7296^*$; $r_{14.3} = +.5063$; $r_{14.32} = +.5743$.

The multiple correlation coefficient calculated for these four factors equalled .8085*, while that for brown heart, sunshine and rainfall was .7847*.

* Exceeds the 5 per cent level of significance.

FIGURE 1. An outdoor trial to determine the nutritional requirements—particularly B, K and Ca. Note the double pot arrangement. Litter was spread on the surface to prevent soil splashing.

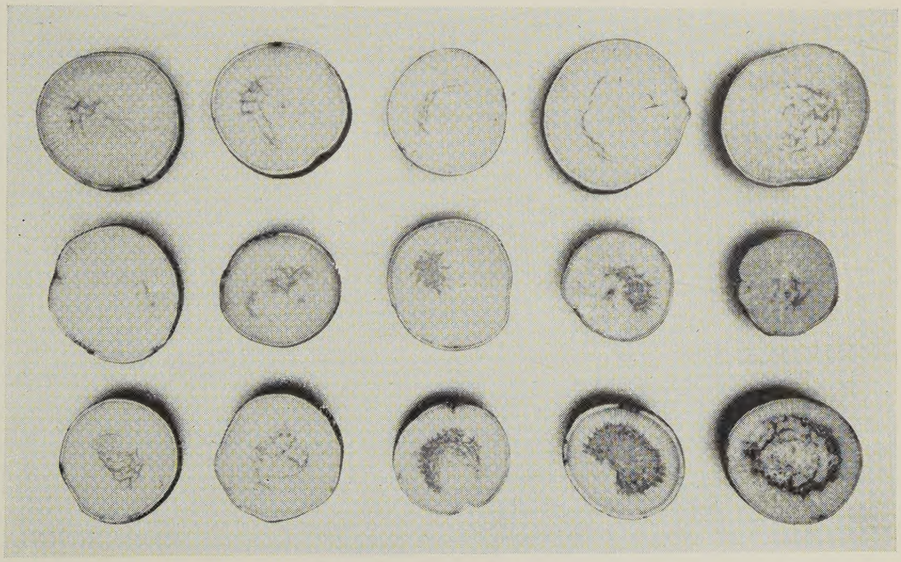

FIGURE 2. Various degrees, patterns and placements of the brown heart areas in affected roots. Of those illustrated, even those with the highest degree fail to show any clear external evidence of the malady.

Although plant vigour was not significantly correlated with average percentage brown heart, when the average sizes of roots with and without brown heart were tabulated, striking differences became apparent (Table 2).

TABLE 2.—THE RELATIONSHIP OF BROWN HEART TO PLANT VIGOUR

(Diameter of roots in inches)

Year	Av. size of roots	Av. size with brown heart	Av. size without brown heart
1933	4.97	5.35	4.66
1934[1]	4.72	5.06	4.24
1936	4.94	5.13	4.85
1937	4.79	4.99	4.54
1938	4.21	4.29	4.05
1939	4.10	4.54	4.05
1940	4.34	4.54	4.30
1941	4.37	4.71	4.25
1942	4.68	4.84	4.58
1943	4.64	4.93	4.47
1944	4.19	4.39	4.18
Mean ± S.E.	4.541 ± .094	4.797 ± .100	4.379 ± .078

[1] No results available from non-borax treated plots in 1935.

Comparisons made by calculating the S.E. of an average of a series of means (Mean ± S.E. = 4.572 ± .053) showed the average size of roots with brown heart to be significantly larger than the average size of roots without brown heart.

To determine whether plant vigour or brown heart are related to the severity of the deficiency symptoms, gross correlation coefficients were calculated between these two independent variables and the average degree of brown heart. Though the coefficient for plant vigour and average degree failed to reach significance, that for average percentage brown heart and average degree was .6883*, which would indicate that degree is influenced by the amount of disease developed.

Experimental evidence on the reaction of brown heart to increased soil moisture, during a year when the rainfall for August and September was 6.03 inches, is presented in Table 3 (over the period under study the average rainfall for these two months was 5.99 inches). The values represent the actual percentages recorded. As the two treatments were not randomized, the data could not be subjected to an analysis of variance that would include the treatment effect. However, the twelve main plots were analysed and as no significant differences were found for either blocks or varieties, it was possible to conclude that the variation at least in the direction of blocks was very low.

Although the treatment means are confounded with location, the large difference suggests with some certainty that increased moisture is capable of retarding the development of boron deficiency.

* Exceeds the 5 per cent level of significance.

TABLE 3.—THE EFFECT OF ADDITIONAL MOISTURE ON BROWN HEART DEVELOPMENT

Variety / Treatment	A	B	C	D	D	A	B	C	D	C	B	A	Mean ± S.E.
No water	56.0	78.3	85.7	56.2	53.1	75.9	88.5	72.4	64.3	67.9	68.2	78.6	70.43 ± 3.35
Water	18.5	29.2	38.5	18.5	10.0	50.0	32.1	37.9	24.0	60.0	55.2	76.7	37.55 ± 5.69

Discussion

The results presented suggest a rather close relationship between brown heart and the amount of rainfall received by the crop during the critical months of August and September. While the influence of hours of sunshine on brown heart is not too well defined (when rainfall and root size are held constant it is of little consequence), the duration of sunshine or, conversely, rainfall is definitely linked with the severity of defoliation occurring in August and September. Bright, dry summers favour defoliation, and this check in development may well contribute to the negative correlation between hours of sunshine and brown heart.

The significant relationship found for brown heart and rainfall, when plant vigour was held constant, indicates that the effect of precipitation on brown heart development is not entirely a question of plant vigour. It would appear that rainfall has either some direct action or at least is closely linked with a factor that tends to increase the prevalence of this disorder.

Plant vigour was not significantly correlated with brown heart, which may be due to the fact that diameter measurements are not truly representative of plant vigour. Boron deficient roots were, however, consistently larger than normal ones.

The decrease in brown heart recorded when the normal moisture supply was supplemented by irrigation becomes difficult to explain, for rainfall increased the disorder.

The possibility exists, however, that a constant supply of moisture might have a more favourable effect on the boron status of the soil than intermittent precipitation.

TIME OF DEVELOPMENT

A knowledge of the period when boron deficiency develops is of primary importance to a proper understanding of control measures, particularly those involving borax applications at different times during the growing season. Accordingly a number of trials were designed to follow the course of the disease.

Results

Preliminary work made it evident that cutting should begin at a relatively early date, and the results obtained from a later experiment are summarized in Table 4. An analysis of variance showed highly significant differences for time of cutting and varieties. Roots examined on July 30 and August 10 had significantly less brown heart than all other dates, while August 23 had less than the dates September 19 to October 27, inclusive.

TABLE 4.—TIME OF BROWN HEART DEVELOPMENT

(Mean percentage brown heart for four varieties)

July	August		September				October		
30	10	23	4	11	19	30	6	16	27
2.2	8.1	34.8	41.2	45.5	52.9	52.8	68.1	52.7	63.2

Least difference = 15.12.

In this trial the major increase in disease occurred between August 10 and August 23, while a more gradual rise took place between August 23 and September 19.

The average degree of brown heart at the various dates as well as the average root size was also analysed statistically. In both instances the "F" test was significant for time of development.

Discussion

That the disease develops very rapidly is clearly shown with the greatest increase occurring over a period that probably does not exceed one week. This sharp rise in percentage brown heart is not reflected in the average size of the roots, which for the most part increased gradually. While average degree was found to be positively correlated with percentage brown heart, it was interesting to note that the sharpest rise in degree occurred between August 23 and September 4, rather than between August 10 and August 23 as might be anticipated which suggests that a period of about two or three weeks only is necessary for the development of severe deficiency symptoms.

VARIETAL SUSCEPTIBILITY

The question of varietal susceptibility is rather indefinite, but for the most part purple-topped varieties are thought to be more susceptible to boron deficiency than green-topped ones (1, 10, 32). The partial resistance of locally developed strains has been suggested (40), while resistant varieties appear to possess greater root systems than non-resistant varieties (32). Chandler *et al.* (4) have observed that while boron deficient plants are commonly described as having reduced root systems, deficient swedes have as many grams of roots per gram of leaves or stem as healthy ones.

Susceptibility to brown heart is complicated by the lack of agreement between varieties grown in different years, where on the same soil type the amount of disease in a variety may be negligible one year and the following year be so severe as to render the crop useless. This is clearly seen by an examination of Table 5, where the mean percentage disease is shown, for four inbred strains.

As these varieties were inbred in alternate years over the period shown in Table 5 one would expect a fairly constant reaction to environmental conditions. This assumption did not hold, for while Bangholm was high in percentage brown heart in 1933 and relatively low in 1936, Corning was low in 1933 and high in 1936. Few exceptions occurred, however, in the consistent behaviour of Ditmar's and Sludsgaard.

TABLE 5.—THE REACTION OF INBRED SWEDE STRAINS TO BROWN HEART

(Mean percentage brown heart)

Inbred strain	Year					Average
	1933	1934	1936	1940	1942	
Corning 4825-1-4	29.0	62.4	72.0	2.4	10.5	35.26
Ditmar's bronze top 1327-4	11.2	21.6	0.0	2.4	5.3	8.10
Bangholm 8112-4-5-5-4	65.2	80.0	36.9	1.6	40.5	44.84
Sludsgaard 325-5-3	72.6	76.8	85.1	58.4	42.7	67.12

This type of reaction suggests that the analysis of data for one or two years is limited in its application. While some varieties may have generally more or less disease than others, one can expect to find varieties that do not exhibit any well defined tendency.

Data available from comparative tests conducted over the past twelve years were analysed with a view to drawing conclusions as to the relative susceptibility of the following varieties:—Acadia, Bangholm 8112, Bangholm 8312, Corning, Ditmar's Bronze Top, Laurentian, Pajberg, Sludsgaard and Wilhelmsburger.

The outstanding feature of the results obtained was the extreme susceptibility to brown heart shown by Sludsgaard and Bangholm 8312 and the partial resistance of Corning and Ditmar's. Within the intermediate group Pajberg and Laurentian were apparently inferior to Bangholm 8112, Acadia and Wilhelmsburger.

Laurentian and Bangholm 8112 may have developed some resistance through selection, for the closely related strain Bangholm 8312 carried appreciably more disease.

BORAX APPLICATIONS

The first borax trials that were conducted involved the rather low rates of application that at the time were proving satisfactory in the Maritime Provinces (26). From these experiments it became evident that borax broadcast at 5, 10 and 20 pounds per acre did not furnish adequate control at this location. Therefore, a series of complex experiments were carried out during the following years (1935, 1936, 1937 and 1938) with a view to arriving at an effective rate, time and method of applying borax.

The control measures for 1937 and 1938 were identical and the findings for these two years are summarized in Table 6. These trials made use of two varieties (Corning and Laurentian); two rates of borax (twenty-five and fifty pounds per acre); two methods of application (*a*) broadcast, (*b*) applied in narrow bands on either side of the row; and two times of application (before seeding and after the appearance of brown heart).

Significant differences were found for rates, times and methods and the interaction of times $\times$ methods. The interaction of years on treated vs. untreated and years on treated plots were also significant, which draws

TABLE 6.—RATES, TIME AND METHODS OF APPLYING BORAX
(Mean percentage brown heart)

Applied at time of seeding				Applied at appearance of brown heart				Check
Bands		Spread		Bands		Spread		
25	50	25	50	25	50	25	50	
10.85	3.37	27.03	16.90	30.00	23.63	31.80	23.33	37.77

Least difference = 5.13.

attention to the fact that when the incidence of brown heart is low, the differences between treated plots and checks, and between the treated plots themselves, is reduced.

All treatments had significantly less brown heart than the check, while band applications of borax made at time of seeding were superior, at either rate, to all other treatments.

That borax may have a very slight effect when the incidence of boron deficiency is not very pronounced is brought out by the limited results for 1939 (Table 7), when twenty-five and fifty pounds of borax broadcast before seeding failed to bring about a significant reduction in brown heart.

TABLE 7.—RATES OF BORAX—1939

Pounds of borax per acre	0	25	50
Mean percentage brown heart	13.2	12.6	10.0

A similar experiment, including an additional ten pound rate, was initated in order to add further evidence to the efficiency of heavy rates of borax broadcast before seeding. These results for the years 1940, 1941 and 1942 are presented in Table 8. All treatments proved to be significantly different from one another and the check, whilst fifty pounds of borax promoted very adequate control.

TABLE 8.—RATES OF BORAX—1940, 1941 AND 1942

Pounds of borax per acre	0	10	25	50
Mean percentage brown heart	64.4	34.2	15.5	3.9

Least difference = 9.78.

Trials based upon work conducted by Coulson and Raymond (9) in 1935, and control measures recommended for the calcareous soils in Ontario by MacLachlan (24) were laid out to test the efficiency of various borax spray schedules. In addition, the foliage sprays were compared with borax (twenty-five to fifty pounds per acre) added to the soil before seeding in bands on either side of the row.

Sprays were employed at four definite times: (1) when the roots were 1-1½ inches in diameter; (2) two weeks later; (3) one month later, and (4) as a split spray.

All treatments reduced the percentage brown heart significantly and the superiority of borax sprays over soil treatments can readily be seen by an examination of Table 9.

TABLE 9.—BORAX SPRAYS

(Mean percentage brown heart)

Spray							Soil		Check
Roots, 1-1½ in.		Two weeks		One month		Split spray	Seeding time		
8	16	8	16	8	16	8 + 8	25	50	
0.96	0.00	5.90	0.00	12.60	9.90	0.00	52.60	30.50	64.30

Least difference = 7.61.

The eight and sixteen pound borax sprays, applied at one month, gave significantly less control than the other spray schedules with the exception of eight pounds at two weeks. Dry borax added to the soil was far from satisfactory but again fifty pounds per acre reduced the disease to a greater extent than did twenty-five pounds.

Discussion

The extensiveness of these trials furnishes the basis for a number of generalizations on the use of borax as a control measure. In the first place the variable responses encountered with soil application of borax are such that the effectiveness of any one treatment may be expected to fluctuate widely when it is conducted over a number of years. Applications of dry borax at seeding time or before the disease has developed extensively are to be desired, and broadcast treatments are inferior to borax applied in bands on either side of the row. The evidence available, however, would suggest that in many years broadcasting is comparable to band applications, and in the absence of banding machinery it may be considered the best method of applying borax to the soil.

Fifty pounds of borax per acre gave fairly consistent control which is well illustrated by an average of only 3.9 per cent brown heart for plots so treated in the years 1940, 1941 and 1942. In contrast to these results the non-uniformity so often encountered is exemplified by the data obtained in 1945, when 30.5 per cent of the roots suffered from brown heart in plots that received fifty pounds of borax per acre applied in bands on either side of the row. This poor control may be explained in part by the heavy precipitation received after the borax had been applied, and the resultant loss of boron through leaching, for Lynch (23) has recommended repeating borax treatments when they are followed by excessive rainfall.

White-Stevens (47) has also mentioned the need for higher rates of borax in wet years. The value of borax sprays in this locality is well established. They appear to be superior to soil treatments, at least in

those years when environmental circumstances are such that the borax applied to the soil is rendered ineffective. The period over which sprays may be used effectively seems to be relatively broad provided that the plants are sprayed before brown heart becomes prevalent.

POTASH FERTILIZATION

Potassium appears to influence the development of boron deficiency, possibly as a result of its interaction with calcium (35) and it has been reported both to increase (48) and to decrease (35) the incidence of deficiency symptoms.

Reeve and Shive (34) summarize the potassium- and calcium-boron relationships as follows:—Increased concentrations of calcium and potassium are very similar in their capacity to accentuate boron deficiency, although calcium lessened the effect of toxic boron levels in which respect its influence was opposite to the accentuating action of potassium. In their investigations potassium intensified boron deficiency in spite of a corresponding rise in the boron content of the plants.

A limited field experiment designed to test the reaction of potash fertilization alone and in combination with standard brown heart control measures is reported. Muriate of potash at 250 pounds per acre was applied alone, and with twenty-five pounds of dry borax and a split borax spray. The potash and dry borax were placed in bands on either side of the row before seeding, while the sprays were applied directly to the foliage.

Definite trends were observed when the roots were scored for brown heart, and a summary of the mean percentage of disease is presented in Table 10. An analysis of variance showed a highly significant difference to exist for the split spray vs. the check and twenty-five pounds of borax. The check and twenty-five pounds of borax are significantly different and though potash increased the amount of brown heart with all treatments this increase was not significant.

TABLE 10.—POTASH FERTILIZATION

(Mean percentage brown heart)

Treatment		25 lb. of borax	Split borax spray
Potash	Check		
0	77.03	63.56	0.76
250 lb.	86.05	68.96	1.55

Discussion

While this experiment suggests that boron deficiency increases with heavy potash fertilization, the results failed to reach significance.

Little disease developed in plots receiving the split-spray, but when potash was added to the check and twenty-five pounds of dry borax the amount of brown heart increased 11.7 and 8.5 per cent, respectively.

NUTRITION STUDIES

A close relationship has been observed between calcium and boron by a number of investigators (21, 29, 38, 41, 44). Drake *et al.* (13) suggest that boron starvation results when the calcium-boron ratio in the plant becomes unfavourable, and the importance of this ratio has been stressed on numerous occasions (20, 22, 39). That potassium is involved in the development of boron deficiency and toxicity has also been noted (5, 17, 34, 35).

Complex trials were laid out to measure the response of the swede to different levels of boron calcium and potassium. A preliminary 3 × 5 × 5 factorial experiment (B .1, .5 and 75 p.p.m.; Ca 20, 40, 100, 200 and 600 p.p.m.; K 10, 20, 100, 200, and 600 p.p.m.) was set up in the greenhouse. This was supplemented by a 4 × 3 × 3 experiment (B .1, .4, 1 and 2 p.p.m.; Ca 80, 200 and 800 p.p.m.; K 80, 200 and 800 p.p.m.) conducted outdoors.

Results and Discussion

Greenhouse Trial

Brown heart was general at .1 p.p.m. boron except when low K (10 and 20 p.p.m.) was associated with high Ca (200 and 600 p.p.m.). In this series high Ca and high K interacted to produce severe brown heart, whereas at the .5 boron level deficiency symptoms were confined to plants receiving the highest level of K (600 p.p.m.) and low Ca (20, 40 and 100 p.p.m.).

K significantly increased the fresh weight of the bulbous roots, their percentage dry matter and the dry weights of the fibrous root system. On the other hand, while Ca significantly increased the weight of the bulbous and fibrous roots it did not alter the percentage dry matter.

Differences were not observed between the .1 and .5 boron levels with respect to root weight, extent of fibrous root system or percentage dry matter, but boron at 75 p.p.m. depressed these three factors and tended to mask the effect of Ca and K.

The fact that in general calcium failed to intensify boron deficiency supports the findings of Chandler (3), who was unable to show a significant difference in boron deficiency when the calcium concentration of his nutrient solutions ranged from 64 to 602 p.p.m.

Outdoor Trial

The method devised for growing swedes outdoors proved to be satisfactory, and the effect of potassium, while not significant, indicated the same general result as in the greenhouse trials.

SEED PRODUCTION

Seed production from boron deficient swedes has not been extensively studied and further information on this question would be of practical importance. From the limited data available the suggestion has been advanced (12) that when seed roots have been produced on land treated with borax there is little to be gained from applications of borax to the seed crop itself.

In order to appraise the effect of brown heart on seed production a total of twenty-four mature swede roots were selected on the following basis. Six healthy and six diseased roots (determined by removing a core from the lower half of the roots with a $\frac{3}{8}$ inch cork borer) were chosen from a block that did not receive borax. The remaining twelve were taken as follows: six from a block that received two borax sprays, and six from a block averaging over sixty per cent brown heart.

Three roots from every set of six did not receive boron, while the remaining three received 2 p.p.m. at weekly intervals.

Results and Discussion

Roots that had brown heart as determined by plugging or those that might be suspected of having this disorder in view of their previous history, failed to complete their growth when boron was withheld. Disease-free roots developed normally without boron while boron at 2 p.p.m. resulted in fair to good seed yields in all series (see Table 11).

Thus the necessity of applying borax to a swede crop from which roots are to be selected for seed production is suggested, together with the fact that supplying borax to the seed crop itself might be a useful measure to ensure optimum seed yields.

TABLE 11.—OBSERVATIONS ON SEED POD PRODUCTION
(Three replications shown)

Boron p.p.m.	Group "A" (plugged)		Group "B" (not plugged)	
	No brown heart	Brown heart	Produced with borax	Produced without borax
0	O, F, G[1]	O, O, O	F, G, G	O, P,*
2	F, G,*	F, G,*	G, G, G	F, G, G

[1] Seed pod production: Good—G; Fair—F; Poor—P; Boron deficiency and eventual death—O.
* Observations on plants prevented by severe mosaic.

SUMMARY AND CONCLUSIONS

The results obtained from the study of brown heart in field grown swedes for the years 1933 to 1945, inclusive, are reported, together with a series of controlled experiments.

The months of August and September are critical with respect to brown heart development, the disorder being positively correlated with the amount of rainfall received during these two months and negatively correlated with hours of sunshine.

Brown heart develops very rapidly with the greatest increase occurring over a one to two week period in the middle of August.

The varieties Corning and Ditmar's possess a fair degree of resistance.

In this particular area borax sprays applied to the foliage are superior to soil applications of dry borax as a method of controlling brown heart.

Potassium accentuated boron deficiency in sand cultures, but in the single field trial reported its effect was not significant.

Roots that are selected for seed production should be free of brown heart.

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ÉTUDES SUR LA POURRITURE DU CERNE DES POMMES DE TERRE CAUSÉE PAR *CORYNEBACTERIUM SEPEDONICUM* (SPIECK. & KOTT). SKAPTASON & BURKHOLDER

I. LES AGENTS DE DISSÉMINATION[1]

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INTRODUCTION

La propagation rapide de la pourriture du cerne (flétrissure bactérienne) dans les centres de production de pommes de terre de la province de Québec nous a incité à étudier, dès 1937, les agents de dissémination de cette maladie. Malgré les mesures sanitaires recommandées par les autorités pour enrayer l'épidémie, celle-ci prit des proportions alarmantes et menaça de destruction l'une de nos plus importantes récoltes. En 1936, Savile et Racicot (21) ont isolé l'agent pathogène, mais à cette époque on ne soupçonnait pas encore toute sa virulence sur nos variétés commerciales de pommes de terre, quoique des essais préliminaires, à Sainte-Anne-de-la-Pocatière, nous aient démontré que la maladie peut se transmettre par des tubercules provenant d'une récolte malade utilisée comme semence, ainsi que par le couteau, lors de l'éclatage des tubercules (1, 18, 20).

Cependant, avant de déterminer les moyens de lutte les plus appropriés, il convenait d'établir l'importance des divers agents susceptibles de propager cette maladie, tels que le couteau, la semence, les instruments aratoires, les insectes, le sol, les sacs, les boîtes, etc. Diverses expériences ont été exécutées et les résultats rapportés très brièvement dans les divers rapports du ministère fédéral de l'Agriculture. Elles sont décrites ici, au fur et à mesure que nous en étudions les différentes phases.

PARTIE EXPÉRIMENTALE

Dissémination par le couteau

A cause de l'expansion rapide que prenait la maladie dans le champ, on se demanda si le couteau ne jouait pas un rôle, insoupçonné jusqu'ici, dans la transmission de l'agent pathogène, des tubercules malades aux tubercules sains, lorsque le cultivateur tranche ses pommes de terre pour les mettre en terre.

Un essai préliminaire fait en serre, dès janvier 1938, démontra immédiatement l'importance du couteau dans la dissémination de la maladie. On éclata dix groupes de trois tubercules avec un couteau contaminé. Mais avant de trancher les tubercules de chaque groupe, on contamina la lame en tranchant un tubercule gravement atteint de pourriture du cerne. Les éclats de chaque tubercule ont été plantés à la suite, dans des pots de neuf pouces, afin de pouvoir retracer l'origine de chaque plant. Les résultats de ce travail révèlent qu'un couteau, contaminé par le passage de sa lame dans un tubercule malade, peut infecter les éclats de trois tubercules coupés l'un après l'autre.

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TABLEAU 1.—POURCENTAGES D'INFECTION DES UNITÉS ET DES BUTTES RÉSULTANT DE L'ÉCLATAGE DE VINGT TUBERCULES CONSÉCUTIFS AVEC UN COUTEAU CONTAMINÉ. LES POURCENTAGES REPRÉSENTENT LA MOYENNE DE DIX RÉPÉTITIONS À SAINTE-ANNE ET À MONT-JOLI

Rang des tubercules	Pourcentages d'unités malades			Pourcentages de buttes malades		
	Sainte-Anne	Mont-Joli	Moyenne	Sainte-Anne	Mont-Joli	Moyenne
1er	100	100	100	95.0	92.5	93.8
2e	100	100	100	95.0	90.0	92.5
3e	100	80	90	90.0	62.5	76.3
4e	100	90	95	85.5	65.5	75.0
5e	100	80	90	82.5	52.5	67.5
6e	100	100	100	80.0	62.5	71.3
7e	100	70	85	70.0	35.0	52.5
8e	90	80	85	82.5	42.5	62.5
9e	100	60	80	65.0	37.5	51.3
10e	80	60	70	57.5	27.5	42.5
11e	90	40	65	52.5	25.0	38.8
12e	90	60	75	37.5	32.5	35.0
13e	80	60	70	42.5	22.5	32.5
14e	90	50	70	52.5	20.0	36.3
15e	80	50	65	40.0	27.5	33.8
16e	80	30	55	42.5	12.5	27.5
17e	80	30	55	50.0	17.5	33.8
18e	70	0	35	37.5	00.0	18.8
19e	60	0	30	25.0	00.0	12.5
20e	50	10	30	35.0	2.5	18.8

La même expérience a été reprise en serre avec six groupes de six tubercules. Les résultats ont été semblables à ceux que l'on a obtenu dans l'essai antérieur; la presque totalité des buttes ont été atteintes de la maladie. Il était évident que le couteau portait suffisamment de bactéries pour infecter les éclats de six tubercules consécutifs.

Ce travail a été répété dans le champ, en 1938 (2), avec dix groupes de dix tubercules et, en 1939 (3), à Sainte-Anne-de-la-Pocatière ainsi qu'à Mont-Joli avec dix groupes de vingt tubercules. Les tubercules de chaque groupe ont été éclatés successivement en quatre morceaux avec un couteau que l'on a contaminé avant de trancher chaque groupe de tubercules. Les éclats de chaque tubercule ont été plantés à la suite dans le rang, avec un espace de trois pieds séparant chaque unité*, nous permettant ainsi d'établir plus facilement le degré d'infection de chacune. Les résultats de ces dernières inoculations sont exposés dans le premier tableau où l'on peut se rendre compte de la gravité de la maladie dans les diverses unités, de la première à la vingtième. Les pourcentages d'infection, tant chez les unités que chez les buttes malades représentent la moyenne de dix répétitions ou groupes.

On constate que le couteau peut infecter les éclats du vingtième tubercule. Que l'infection soit plus grave parmi les premiers tubercules éclatés que parmi les derniers cela se conçoit très bien, alors que la lame du couteau que l'on a contaminée est partiellement essuyée et nettoyée,

* On a désigné sous le nom d'*unité* l'ensemble des éclats ou morceaux, généralement quatre, provenant d'un même tubercule. Ces éclats du même tubercule sont mis en terre à la suite l'un de l'autre, permettant ainsi de retracer l'origine de chaque butte. Entre la dernière butte de la première unité et la première butte de la deuxième unité on laisse un espace de deux à trois pieds. Cette méthode de plantation est connue sous l'expression de plantation par unités ou tubercules isolés.

chaque fois qu'elle tranche un tubercule sain. Dans certains cas, la maladie ne s'est pas transmise plus loin que les douzième et treizième tubercules, mais il suffit de savoir qu'elle peut se transmettre aux buttes issues du vingtième tubercule pour démontrer la virulence de l'agent pathogène. Le degré d'infection a été plus élevé à Sainte-Anne-de-la Pocatière qu'à Mont-Joli, mais on ne peut expliquer cette différence, attribuable, à divers facteurs, tels que la viabilité et la virulence des bactéries contenues dans le tubercule d'où provient l'inoculum, les conditions climatiques, etc.

Les résultats de cette expérience sont condensés dans la figure 1 et analysés dans les tableaux 2, 3 et 4.

Si l'on réfère au tableau 2 on constate que la maladie a été observée dans 87 p. 100 des unités à Sainte-Anne-de-la-Pocatière, tandis que 57 p. 100 des unités étaient atteintes de flétrissure à Mont-Joli.

Ces chiffres signifient que le producteur de semence qui plante ses pommes de terre selon la méthode du tubercule isolé peut être obligé de rejeter, comme impropres à la semence, 57 à 87 p. 100 de ses unités, si la semence qu'il a utilisée contient 5 p. 100 de tubercules atteints de flétrissure.

Si l'on considère maintenant le nombre de plants malades, on peut voir au tableau 3 que 60 p. 100 des buttes étaient atteintes de flétrissure à Sainte-Anne-de-la-Pocatière et qu'à Mont-Joli 36 p. 100 des plants manifestaient les mêmes symptômes.

Tableau 2.—Taux d'infection de dix groupes de vingt tubercules (unités) éclatés avec un couteau contaminé

Pourcentages et degrés[1]	Localités	
	Sainte-Anne-de-la-Pocatière	Mont-Joli
Pourcentage	87.0[2]	57.5
Degrés	71.7 ± 3.9	49.6 ± 3.9
D.M.S.[3]	± 11.5	

[1] Les pourcentages n'ont été analysés qu'une fois transformés en degrés angulaires.
[2] La moyenne de 10 répétitions (10 groupes de 20 tubercules).
[3] La différence moyenne significative.

Tableau 3.—Taux d'infection de dix groupes de quatre-vingts éclats avec un couteau contaminé

Pourcentages et degrés[1]	Localités	
	Sainte-Anne-de-la-Pocatière	Mont-Joli
Pourcentage	60.3[2]	36.4
Degrés	51.1 ± 2.8	36.8 ± 2.8
D.M.S.[3]	± 8.3	

[1] Les pourcentages n'ont été analysés qu'une fois transformés en degrés angulaires.
[2] La moyenne de dix répétitions (i.e. 10 groupes de 80 éclats ou buttes).
La différence moyenne significative.

Ces observations sont basées sur le diagnostic des symptômes visibles à la surface des tubercules. Il est très probable qu'en tranchant chaque tubercule des buttes apparemment saines, on aurait découvert la maladie là où il n'y avait aucun signe extérieur d'infection et augmenté les pourcentages d'unités et de buttes atteintes de pourriture. Néanmoins, les chiffres donnés dans les tableaux précédents sont assez éloquents et démontrent bien l'extrême virulence de *Corynebacterium sepedonicum* et l'efficacité du couteau comme agent de dissémination de cet organisme.

TABLEAU 4.—NOMBRES ET POURCENTAGES MOYENS DE BUTTES FLÉTRIES DANS LES PREMIÈRES ET VINGTIÈMES UNITÉS COMPOSÉES CHACUNE DE QUATRE BUTTES

Rang des unités	Nombres		Pourcentages		Moyenne
	Sainte-Anne	Mont-Joli	Sainte-Anne	Mont-Joli	
Premières	3.8[1] ± 0.21	3.7 ± 0.11	95.0	92.5	93.7
Vingtièmes	1.4 ± 0.44	0.1 ± 0.00	35.0	2.5	18.7

[1] La moyenne de 10 répétitions de 4 buttes chacune.

Le tableau 4 représente le degré d'infection dans les premières et vingtièmes unités, tant à Sainte-Anne-de-la-Pocatière qu'à Mont-Joli. On constate que la moyenne des buttes malades dans les premières unités est de 3.8 et 3.7 sur un total de 4 pour l'un et l'autre de ces endroits, soit 95 et 92.5 p. 100 de buttes malades. Dans les vingtièmes unités on a obtenu une moyenne de 1.4 et 0.1 buttes malades sur un total de 4 buttes, soit 35 et 2.5 p. 100, selon l'endroit où l'expérience a été poursuivie. A Sainte-Anne-de-la-Pocatière où 35 pour cent des buttes des vingtièmes unités étaient malades, il est évident que l'infection se serait étendue à un plus grand nombre d'unités si l'on avait éclaté plus que vingt tubercules par groupe. Devant ces résultats étonnants, on peut imaginer l'étendue des dommages que peut causer le couteau lors de la plantation, s'il y a quelques tubercules malades mêlés à la semence.

Depuis 1940, des expériences faites dans le Wyoming (23) et le Colorado (14) ont démontré que le couteau est l'un des principaux agents de dissémination de la flétrissure. Les travaux d'Eddins en 1939 (12) et plus tard ceux d'autres chercheurs (10, 24) ont confirmé les résultats que l'on a obtenus en démontrant que le couteau peut communiquer la maladie jusqu'au vingt-cinquième tubercule.

Puisque le couteau dissémine si facilement la maladie, n'y a-t-il pas avantage à ne planter que des tubercules entiers et éliminer ainsi les dangers de contamination, lors de l'éclatage des tubercules. Durant l'hiver de 1944-1945, cent tubercules apparemment sains, mais provenant de buttes atteintes de flétrissure, ont été plantés en serre. Cinquante de ces tubercules ont été plantés entiers, tandis que les cinquante autres ont été éclatés consécutivement avec le même couteau non-désinfecté, en deux, trois et quatre morceaux selon leur grosseur et plantés en pots de six pouces. Quatre mois après la plantation, un bon nombre de plants, tant dans le premier groupe que dans le deuxième, étaient morts après avoir montré les symptômes de flétrissure. Les résultats de cet essai ont démontré

que 62 p. 100 des tubercules non-éclatés ont produit des plants atteints de flétrissure, tandis que 96 p. 100 des plants provenant de tubercules éclatés ont manifesté les symptômes de la maladie.

Cette expérience a été répétée dans le champ avec de la semence provenant de deux champs contaminés. Cependant, les tubercules ne provenaient pas nécessairement tous de buttes atteintes de flétrissure puisqu'ils avaient été choisis au hasard dans les caves. Les résultats exposés dans le tableau 5 confirment ce que l'on a déjà obtenu en serre, savoir, la plantation de tubercules entiers diminue considérablement les ravages de la maladie dans nos champs de pommes de terre.

Tableau 5.—Pourcentage des buttes flétries dans deux semences différentes dont un certain nombre de tubercules ont été plantés entiers comparés à d'autres que l'on a éclatés avant de planter

Semences	Pourcentage de buttes malades provenant de tubercules	
	Entiers	Eclatés
A	3	14
B	8	47
Moyenne	5.5	30.5

La différence d'infection entre les buttes provenant de tubercules entiers et celles qui ont été produites de tubercules éclatés est d'autant plus prononcée que le pourcentage de tubercules malades dans la semence est élevé.

Dissémination par la semence

Connaissant le rôle important du couteau dans la transmission de cette maladie, il devient évident que celle-ci ne peut s'étendre avec la rapidité que l'on a vue si elle n'existe pas, tout d'abord, dans la semence. En 1939 (1) on a observé que 50 p. 100 des tubercules provenant d'une récolte malade de flétrissure pouvaient transmettre la maladie, l'année suivante. La même année, Bonde (7), remarque que 50 à 90 p. 100 des plants peuvent être atteints de flétrissure, si l'on met en terre une semence provenant d'une récolte malade. Une récolte peut ne montrer que des traces de flétrissure et, si celle-ci sert de semence l'année suivante, 15 à 40 p. 100 des plants peuvent être atteints de la maladie. D'autres en 1940 (6, 16) font la même constatation.

Il arrive assez souvent qu'un producteur de pommes de terre change de semence dans l'espoir de se défaire de cette maladie. Mais le nombre des cultivateurs qui ne s'en préoccupent pas est encore plus nombreux; croyant avoir éliminé la maladie lorsqu'ils ont enlevé tous les tubercules douteux, ils enfouissent, malheureusement trop souvent, une semence contaminée.

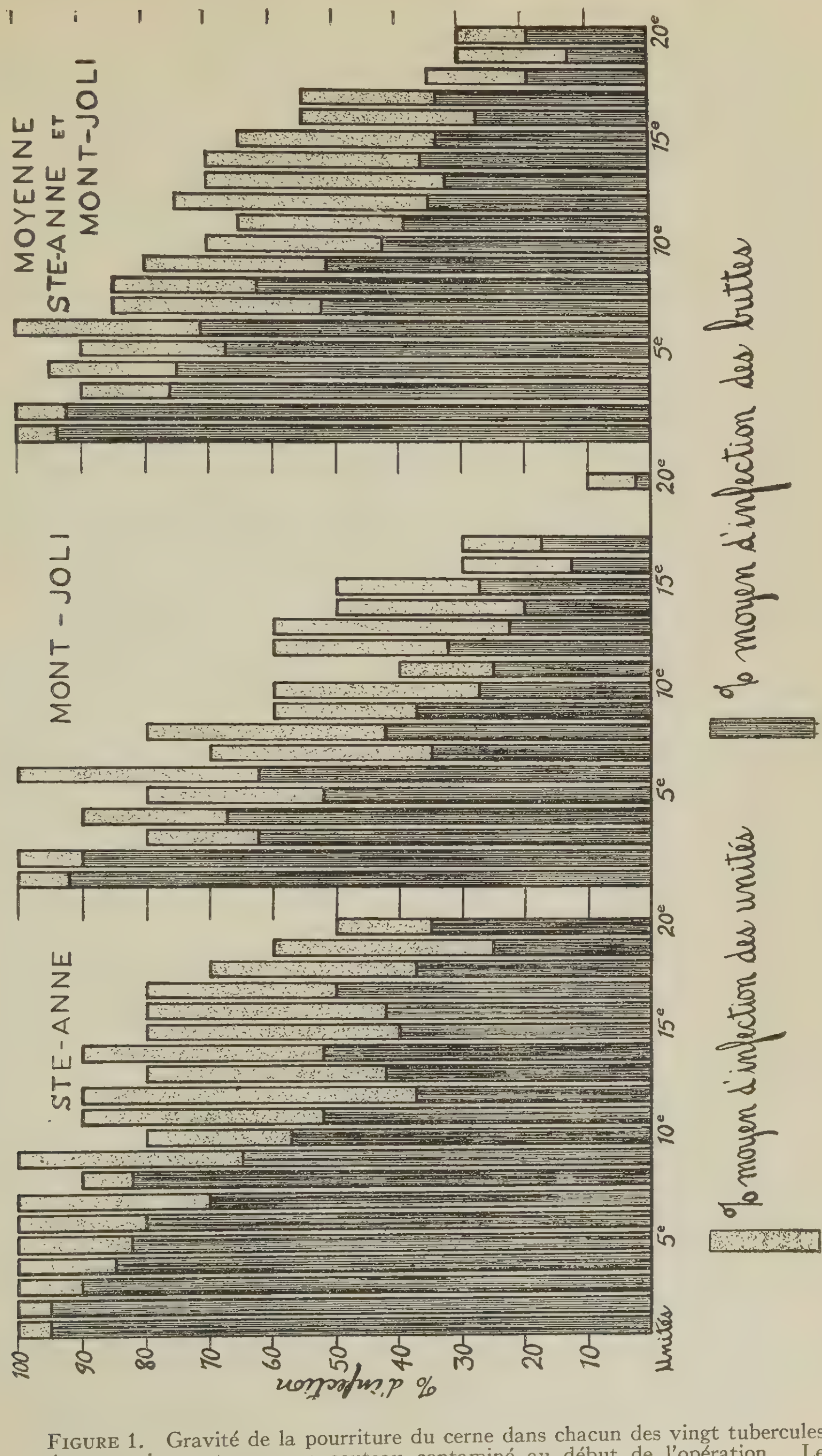

FIGURE 1. Gravité de la pourriture du cerne dans chacun des vingt tubercules coupés successivement avec un couteau contaminé au début de l'opération. Le pourcentage d'infection représente la moyenne de dix répétitions.

Afin d'établir l'importance de la semence comme facteur de dissémination, on a mis en terre, sur deux fermes, des tubercules apparemment sains d'une récolte malade produite l'automne précédent et de la semence certifiée provenant de deux sources différentes. Sur l'une et l'autre fermes, on a obtenu 59 p. 100 et 52 p. 100 de plants flétris dans la semence commune et 2 p. 100 de flétrissure dans l'une des deux semences certifiées. Ces résultats démontrent bien que la maladie était encore présente dans les semences que l'on a utilisées, même dans la semence certifiée que l'on croyait parfaitement saine. Il pouvait n'y avoir qu'un faible pourcentage de tubercules atteints de pourriture du cerne dans la semence, mais le fait de trancher les tubercules avec un couteau accentua la maladie.

Des tubercules provenant de buttes apparemment saines, mais faisant partie d'unités où il y a une ou plusieurs buttes malades, peuvent être porteurs de germes de flétrissure et produire des plants malades (3). Sur un total de 119 de ces tubercules provenant de buttes saines, mais dont les buttes sœurs composant les mêmes unités étaient malades, 29 p. 100 ont donné des plants flétris. Il s'est même présenté des cas où des tubercules provenant de buttes d'unités entièrement saines, du moins en apparence, aient produit des plants flétris. Il faut ajouter que ces unités, saines d'apparence, étaient le résultat d'épuration d'un champ malade antérieurement, démontrant ainsi la possibilité d'une infection latente dans certains tubercules.

Le tableau 6 résume des observations semblables faites sur différentes variétés en 1939. Ces tubercules, sains en apparence, provenaient de buttes flétries récoltées l'année précédente. Ils ont été plantés entiers, afin de mettre en évidence tous ceux qui pouvaient transporter la maladie pendant l'hiver.

Tableau 6.—Hivernement de la maladie dans les tubercules apparemment sains de différentes variétés

Variétés	Nombre de tubercules mis en terre	Buttes montrant les symptômes sur le feuillage		Buttes malades à la récolte, après examen microscopique	
		%	degrés	%	degrés
1 Arran Consul	20	45.0	42.13 ± 8.7	40.0	39.23 ± 9.2
2 Houma	33	36.3	37.05	30.3	33.40
3 Donard	63	30.1	33.27	38.1	38.12
4 Arran Banner	24	33.3	35.24	41.6	40.16
5 Spaulding Rose	6	50.0	45.00	33.3	35.24
6 Prolifique	29	24.1	29.40	13.8	21.81
7 Great Scot	29	41.3	39.99	44.9	42.07
8 Rural Blush	91	5.4	13.44	6.6	14.89
9 Dunbar Yeoman	12	50.0	45.00	41.6	40.16
10 Arran Chief	37	43.2	41.09	37.8	37.94
11 Warba	30	33.3	35.24	20.0	26.56
12 Katahdin	6	33.3	35.24	33.3	35.24
13 Davis Warrior	20	50.0	45.00	35.0	36.27
14 Irish Cobbler	17	11.7	20.00	5.8	13.94
15 Dooley	22	27.2	31.44	31.3	34.02
16 Montagne Verte	44	20.4	26.85	22.7	28.45
17 Sunrise	45	31.1	33.89	33.3	35.24

Ces observations sont basées sur les symptômes extérieurs de la maladie ainsi que sur l'examen microscopique d'empreintes prises sur tous les tubercules lors de la récolte. Le nombre de buttes malades serait probablement légèrement supérieur à celui qui est indiqué dans la dernière colonne du tableau, si l'on avait pu faire l'examen microscopique de chaque tige car, en certains cas, les symptômes étaient apparents sur la tige sans l'être sur les tubercules.

Un certain nombre de cultivateurs ont l'habitude de ne planter que des petits tubercules. C'est une pratique que l'on doit déconseiller, lorsque ces tubercules ne proviennent pas d'une récolte qui a subi favorablement les épreuves de la certification. Les résultats d'un essai fait à Sainte-Anne-de-la-Pocatière, en 1940, confirment cette assertion.

Des gros et des petits tubercules, apparemment sains, mais provenant d'une récolte malade, ont été plantés entiers dans le champ. Les observations faites lors de la récolte ont révélé que les petits tubercules étaient plus souvent porteurs de germes que les gros (4). Des plantations similaires ont été faites l'année suivante à Mont-Joli et à Sainte-Anne avec la récolte de l'année précédente, après avoir séparé les petits des gros tubercules. Les résultats obtenus ont été semblables ainsi que l'on peut le constater en examinant le tableau 7.

TABLEAU 7.—RAPPORT ENTRE LA GROSSEUR DES TUBERCULES ET LA DISSÉMINATION DE LA FLÉTRISSURE

Localités	Types de tubercules mis en terre	Nombre de tubercules plantés	Pourcentage de buttes malades
1939 Mont-Joli	Gros	256	14.1
	Petits	343	18.7
1940 Mont-Joli	Gros	100	1.0
	Petits	200	6.7
Sainte-Anne	Gros	72	1.1
	Petits	147	4.8

Cependant, Sherf (22) en 1944, affirme qu'il ne semble pas y avoir de relation entre la grosseur des tubercules et le nombre de tubercules infectés. Evidemment, il y aurait lieu de reprendre ici sur une plus grande échelle, le travail rapporté plus haut, afin de vérifier ce point.

Dissémination par les instruments aratoires

La planteuse mécanique peut-elle être considérée comme agent de dissémination? En 1939 (3) une expérience conduite chez deux producteurs de pommes de terre dont la récolte était gravement atteinte de flétrissure, démontra le danger de contaminer une semence et de disséminer la maladie chez les voisins, lorsque cet instrument est utilisé pour planter indifféremment des semences saines ou infectées.

Après avoir mis en terre avec la planteuse mécanique, une semence contaminée, on a planté deux rangs de pommes de terre certifiées sans désinfecter auparavant la machine. La plantation terminée, la machine a été décrassée, lavée et brossée à l'eau et ensuite au formol (aldéhyde formique) diluée dans un volume égal d'eau. Deux autres rangs de pommes de terre certifiées ont alors été plantés. L'éclatement de ces tubercules a été fait avec différents couteaux. Ceux qui ont servi pour la semence contaminée ont été éliminés et d'autres couteaux ont été utilisés pour trancher la semence certifiée.

Les résultats rapportés dans le tableau 8 démontrent clairement que la planteuse mécanique peut disséminer la maladie. Sur les deux fermes où l'on a poursuivi cette expérience, il s'est trouvé de la flétrissure dans la plantation même après avoir désinfecté la machine. Il nous a été impossible de déterminer si la semence certifiée utilisée dans cette expérience était déjà contaminée avant de la mettre en terre ou bien, si elle l'a été au contact de quelque partie de l'instrument insuffisamment désinfectée.

TABLEAU 8.—DISSÉMINATION DE LA MALADIE PAR LA PLANTEUSE MÉCANIQUE

Localités	Traitements	Nombre total de buttes	Pourcentage de buttes malades	Nombre de tubercules malades
Mont-Joli	Planteuse désinfectée	354	2.8	22
	Planteuse non-désinfectée	532	7.7	132
Rivière-Ouelle	Planteuse désinfectée	1425	0.2	11
	Planteuse non-désinfectée	1398	2.1	87

Néanmoins, ces résultats doivent convaincre le producteur sérieux à ne pas utiliser ces instruments sans s'assurer qu'ils n'ont pas servi antérieurement à la plantation de pommes de terre malades. La désinfection parfaite de ces machines aratoires est assez difficile et l'on court toujours le risque que certaines parties ne soient pas atteintes par le désinfectant. Cependant, la désinfection est quand même très fortement recommandée lorsque la même machine doit servir à l'enfouissement de diverses semences. Si la désinfection n'élimine pas toujours les dangers d'infection, elle contribue sûrement à diminuer la gravité de la maladie.

Des résultats similaires ont été obtenus dans le Colorado (14) et le Minnesota (10) où l'on a observé que la planteuse mécanique avec pointes dissémine la maladie plus facilement que la planteuse à table rotative.

On s'est souvent demandé si les autres instruments tels que les sarcleuses, les houes, les pulvérisateurs, les tracteurs, etc., ne pouvaient disséminer la maladie dans le champ. Dans deux groupes de trois parcelles comprenant cent buttes chacune, on a mis de la semence certifiée. Dans la première parcelle de chaque groupe, on a enfoui un morceau de pomme

TABLEAU 9.—PROPAGATION ANNUELLE DE LA POURRITURE DU CERNE DANS DES PARCELLES OÙ L'ON A INTRODUIT, EN 1939, UNE, CINQ ET DIX BUTTES MALADES

(Les chiffres en caractères gras indiquent depuis combien d'années les buttes qu'ils représentent sont atteintes de la maladie)

	1%									
1.	0	0	0	0	0	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	0	0
3.	0	0	0	0	0	0	0	0	0	0
4.	0	0	0	0	0	0	0	0	0	0
5.	0	0	0	0	0	**7**	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	0	0	0	0	0	0	0
8.	0	0	0	0	0	0	0	0	0	0
9.	0	0	0	0	0	0	0	0	0	0
10.	0	0	0	0	0	0	0	0	0	0

	5%									
1.	0	0	0	0	0	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	0	0
3.	0	0	**7**	0	0	0	0	**7**	0	0
4.	0	0	0	0	0	0	0	0	0	0
5.	0	0	0	0	**7**	0	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	0	0	0	0	0	0	0
8.	0	0	**7**	0	0	0	0	**7**	0	0
9.	0	0	0	0	0	0	0	0	0	0
10.	0	0	0	0	0	0	0	0	0	0

	10%									
1.	0	0	0	0	0	0	0	0	0	0
2.	0	**7**	0	**2**	0	0	0	0	0	0
3.	0	0	**7**	0	0	0	0	0	0	0
4.	0	0	0	**7**	0	0	0	**4**	0	0
5.	0	0	0	0	**7**	0	0	0	0	0
6.	0	0	0	0	0	**7**	0	0	0	0
7.	0	0	0	0	**7**	0	**7**	0	0	0
8.	0	0	0	0	0	0	0	**7**	0	0
9.	0	0	0	0	0	0	0	0	**7**	0
10.	0	0	0	0	0	0	0	0	0	**7**

	1%									
1.	0	0	0	0	0	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	0	0
3.	0	0	0	0	0	0	0	0	0	0
4.	0	0	0	0	0	0	0	0	0	0
5.	0	0	0	0	**7**	0	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	0	0	0	0	0	0	0
8.	0	0	0	0	0	0	0	0	0	0
9.	0	0	0	0	0	0	0	0	0	0
10.	0	0	0	0	0	0	0	0	0	0

	5%									
1.	0	0	0	0	0	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	0	0
3.	0	0	**7**	0	0	0	0	**7**	0	0
4.	0	0	0	0	0	0	0	0	0	0
5.	0	0	**4**	0	**7**	0	0	0	0	0
6.	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	0	0	0	0	0	0	0
8.	0	0	**7**	0	0	0	0	**7**	0	0
9.	0	0	0	0	0	0	0	0	0	0
10.	0	0	0	0	0	0	0	0	0	0

	10%									
1.	**7**	0	0	0	0	0	0	0	0	0
2.	0	**7**	0	0	0	0	0	0	0	0
3.	0	0	**7**	0	0	0	0	0	0	0
4.	0	0	0	**7**	0	0	0	0	0	0
5.	0	0	0	0	**7**	0	0	0	0	0
6.	0	0	0	0	0	**7**	0	0	0	0
7.	0	0	0	0	0	0	**7**	0	0	0
8.	0	0	**6**	0	0	0	0	**7**	0	0
9.	0	0	0	0	0	0	0	0	**7**	0
10.	0	0	0	0	0	0	0	0	0	**7**

0 Signifie que la butte est saine; **7** signifie que la butte est atteinte de flétrissure depuis sept ans.

de terre inoculé avec *Corynebacterium sepedonicum*, dans la seconde parcelle, cinq morceaux et dans la troisième, dix morceaux inoculés avec le même organisme. Les parcelles comprenaient donc dès la première saison un, cinq et dix pour cent des buttes atteintes de flétrissure. Durant la saison d'été, les travaux ordinaires de culture ont été exécutés et, à l'automne, les tubercules de chaque butte ont été récoltés séparément. Les tubercules ont été examinées et les buttes atteintes de flétrissure éliminées. Toutes les buttes étant numérotées, on a prélevé deux tubercules de celles qui étaient exemptes de flétrissure, pour les conserver en cave et les planter dans le même ordre le printemps suivant. Les buttes atteintes de flétrissure pendant l'année ont été remplacées par des tubercules malades l'année suivante, afin de maintenir les foyers d'infection. On a pu, de la sorte, suivre le progrès de la maladie de saison en saison et déterminer l'importance des travaux de culture dans la propagation de la maladie.

Le tableau 9 résume les observations de sept années, de 1940 à 1946 inclusivement. Il représente la disposition des buttes saines et des buttes malades au sein des parcelles. Les chiffres indiquent depuis combien d'années les buttes qu'ils représentent sont atteintes de flétrissure. On peut constater que la maladie s'est communiquée à quelques buttes saines dans les deux parcelles où il y avait, dès le début, 10 p. 100 de flétrissure. Dans une de ces parcelles, la maladie s'est transportée dès la première année sur la septième butte du cinquième rang. Durant la quatrième année, la quatrième butte du huitième rang était atteinte et la sixième année la deuxième butte du quatrième rang tombait elle aussi. Dans la seconde parcelle, la huitième butte du troisième rang a contracté la maladie

durant la deuxième année. Dans une des deux parcelles où il y avait 5 p. 100 de flétrissure dès le début de l'expérience, la maladie s'est communiquée à la cinquième butte du troisième rang durant la quatrième année.

En 1939, une autre expérience a été conduite à Sainte-Anne-de-la-Pocatière et à Mont-Joli, aux fins de savoir si la flétrissure pouvait se communiquer dans le champ, d'un plant malade à un plant sain. Dix rangs de trente buttes chacun ont été ensemencés avec des tubercules certifiés, alternant avec des tubercules inoculés avec le couteau. Les travaux ordinaires de culture ont été faits durant l'été, de même que les observations nécessaires pour dépister la maladie. Lors de la récolte, les buttes provenant de tubercules sains n'ont montré aucun symptôme de flétrissure, quoique le nombre de plants flétris résultant des inoculations ait été très élevé. La récolte des buttes saines a été conservée en cave pour examen ultérieur. Le printemps suivant, les tubercules ont été examinés, mais aucun ne semblait être atteint de flétrissure. Cinq cents de ces tubercules ont été plantés entiers et les buttes examinées au cours de l'été et lors de la récolte. On n'a jamais eu le moindre doute sur l'état sanitaire de ces plants sur lesquels on n'a vu aucune trace de flétrissure.

Cette expérience a été reprise en 1940 à Sainte-Anne-de-la-Pocatière. Des tubercules sains et des tubercules inoculés ont été plantés alternativement dans dix rangs comprenant chacun vingt-cinq buttes. A l'automne, les plants provenant de la semence certifiée ont donné une récolte saine, tandis que les buttes dont la semence a été inoculée n'ont donné que deux plants sains. Les résultats déjà rapportés (4) sont consignés dans le tableau 10.

TABLEAU 10.—RÉCOLTE PROVENANT DE TUBERCULES INOCULÉS AVEC *C. sepedonicum* ET DE TUBERCULES SAINS PLANTÉS ALTERNATIVEMENT DANS LE CHAMP

Semences	Nombre d'éclats		Pourcentage des buttes	
	Mis en terre	Non-germés	Flétries	Saines
Saine	125	0	0	100.0
Inoculée	125	27	98.4	1.6

La récolte des buttes saines a été conservée en cave et, le printemps suivant, à part quelques tubercules atteints de pourriture causée par la brûlure tardive (mildiou) et autres organismes secondaires, il n'y a eu aucune trace de flétrissure. Trois cents de ces tubercules ont été plantés entiers et les buttes examinées durant l'été et lors de la récolte. Deux buttes ont montré des symptômes de flétrissure, mais il nous est impossible de dire si cette infection a pris naissance dans le champ ou si elle doit être attribuée à un mélange de tubercules, ce qui est toujours possible en cave. Il ressort de ces travaux que la dissémination de la maladie, bien que possible, doit se produire rarement d'une plante à une autre par les diverses façons culturales.

Ces résultats ont, du reste, été confirmés par des expériences poursuivies dans le Montana, la Floride, le Minnesota et la Californie, où l'on a démontré que la maladie ne se transmet pas dans le champ, d'un plant malade à un plant sain, excepté lorsque le système d'irrigation ne fonctionne pas bien (10). Selon certains auteurs, l'eau d'irrigation peut être un facteur dans la dissémination de la maladie (8, 13, 17, 24).

Dissémination par les insectes

En 1940, Metzger et Binkley (17) ont laissé entendre que les altises sont probablement responsables de la dissémination de la maladie dans un champ où elle existe déjà. Il est parfois difficile d'expliquer autrement l'apparition de la flétrissure dans certains champs et les observations que l'on a faites à Sainte-Anne-de-la-Pocatière, il y a quelques années, nous laissent perplexes.

Diverses espèces d'insectes que l'on rencontre communément dans les champs du Bas Saint-Laurent ont été placées sous cages, sur des plants de pommes de terre atteints de flétrissure. Après s'y être nourris durant quinze jours, ils ont été transférés sur des tiges saines également sous cages. Cinq jours plus tard, on a fait l'examen microscopique des pétioles et des nervures médianes des feuilles sur lesquelles se nourrissaient les insectes, mais on n'y a trouvé aucune trace de *Corynebacterium sepedonicum.*

Divers insectes qui se nourrissaient sur des plants de pommes de terre atteints de flétrissure ont été captés dans le champ et examinés au microscope, afin d'y déterminer la présence de *C. sepedonicum.* Les insectes ont été écrasés sur des lames de verre et les empreintes colorées selon la méthode Gram. Dans le tableau 11 où sont résumées les observations, on constate que sur soixante et onze individus examinés, une quinzaine portaient des micro-organismes qui ressemblaient à *Corynebacterium sepedonicum.*

TABLEAU 11.—PRÉSENCE D'ORGANISMES RESSEMBLANT À *Corynebacterium sepedonicum* DANS DIVERSES ESPÈCES D'INSECTES

Nom de l'insecte	Nombre d'individus examinés	Empreintes	
		Positives	Douteuses
Lygée terne (*Lygus pratensis*)	15	4	3
Altise (*Epitrix cucumeris*)	31	1	2
Cicadelle (*Philaenus pallidus*)	13	5	2
Puceron (Espèce non-déterminée)	8	3	1
Doryphore (*Leptinotarsa decemlineata*)	4	2	—

Certains prétendent que même si les insectes peuvent porter la maladie d'une plante à une autre, il est peu probable que l'agent pathogène puisse atteindre les tubercules durant la saison, à cause de son avance excessivement lente dans les vaisseaux de la tige. Des résultats que l'on n'a pas encore publiés démontrent que la flétrissure peut apparaître sur les tiges six semaines après la plantation de tubercules inoculés. Après cette période d'incubation les bactéries sont déjà en abondance dans un certain nombre de feuilles. Des inoculations pratiquées sur des feuilles ont produit, un mois plus tard, le flétrissement des tiges et la pourriture d'un certain nombre de tubercules à la maturité des plants. Il est vrai que ces résultats ont été obtenus en serre, mais on ne peut faire autrement que d'admettre que la maladie peut parfois atteindre les tubercules formés durant la saison de végétation, lorsque l'infection ne se produit pas trop tard. Mais il reste encore à démontrer que certains insectes peuvent transmettre la maladie.

Dissémination par le sol

Afin de savoir si l'organisme peut hiverner dans le sol et envahir la semence le printemps suivant, un certain nombre de tubercules provenant de semences certifiée et non-certifiée ont été plantés, en 1937, dans un sol où il n'y avait jamais eu de pommes de terre et dans un autre sol qui avait produit une récolte gravement infectée de pourriture du cerne l'année précédente. Les résultats rapportés dans le tableau 12 démontrent bien que sous les conditions climatiques du Québec, l'organisme, s'il hiverne dans le sol, n'est pas suffisamment virulent le printemps suivant pour infecter la semence que l'on met en terre (18). La semence certifiée n'a produit que des plants sains, tant dans le terrain contaminé que dans le terrain non-contaminé. La semence commune qui a donné des plants malades dans le terrain non-contaminé n'en a pas donné davantage dans le terrain contaminé.

Tableau 12.—Pourcentage des plants malades provenant des semences de pommes de terre certifiées et non-certifiées mises en terre contaminée et en terre non-contaminée

Localités	Semence certifiée				Semence non-certifiée			
	Sol non-contaminé		Sol contaminé		Sol non-contaminé		Sol contaminé	
	Nombre de plants	Pourcentage de plants flétris	Nombre de plants	Pourcentage de plants flétris	Nombre de plants	Pourcentage de plants flétris	Nombre de plants	Pourcentage de plants flétris
Mont-Joli	151	0	147	0	161	8	151	14
Saint-Félix	149	0	153	0	145	14	143	11

En 1937, on s'est procuré de la semence certifiée de huit sources différentes que l'on a enfouie dans les mêmes sols que pour l'expérience précédente. Les observations que l'on a résumées dans le tableau 13 démontrent, encore une fois, qu'il n'y a pas plus de plants malades dans le terrain contaminé que dans le terrain non-contaminé. Quelques-unes de ces semences étaient atteintes de pourriture du cerne, les autres en étaient exemptes. A la fin de cette expérience les semences qui étaient exemptes de flétrissure ont produit des plants sains, tant dans le sol contaminé que non-contaminé. Quant aux semences porteuses de germes de la maladie, elles n'ont pas donné plus de plants malades dans un sol que dans l'autre.

La même année, des tiges et des tubercules atteints de flétrissure ont été étendus sur le champ en quantité suffisante pour couvrir une superficie de 1/10 d'arpent et le tout a été légèrement enfoui avec la herse à disques avant les gelées d'automne. Le printemps suivant, cette superficie a été ensemencée avec des pommes de terre certifiées, mais à l'automne aucune trace de flétrissure n'a pu être observée sur les tiges ou sur les tubercules. Deux cents tubercules de cette récolte ont été plantés au printemps 1939, au cas où il y aurait eu infection latente des tubercules et que la maladie se serait manifestée la deuxième année, mais les résultats ont été négatifs.

TABLEAU 13.—ANALYSE DES RÉSULTATS OBTENUS À LA SUITE DE LA PLANTATION DE POMMES DE TERRE PROVENANT DE HUIT PRODUCTEURS DANS DES SOLS CONTAMINÉS ET NON-CONTAMINÉS SUR DEUX FERMES DU QUÉBEC

	Mont-Joli	Saint-Félix
Moyenne des différences (Sols contaminés et non-contaminés)	1.12	−0.50
de la moyenne des différences	1.47	0.37
Valeur de t	0.76*	1.35*

* Ces valeurs ne sont pas significatives.

Cette dernière expérience a été reprise en 1940 et répétée l'année suivante. Chaque année, la récolte a été conservée en entrepôt et mise en terre le printemps suivant, afin de dépister toute trace de flétrissure dans les tubercules. Mais durant cette expérience comme dans la précédente, aucune trace de maladie n'a pu être observée.

Dans une autre expérience, des tubercules gravement atteints de flétrissure ont été écrasés et mêlés au terreau dans la proportion d'une partie de pulpe de patates pour trois parties de terreau. Le tout a été mis dans des boîtes de bois et soumis aux intempéries de l'hiver 1938-1939. Au mois d'avril, le terreau, une fois dégelé, a été mis dans une centaine de pots de 6 pouces de diamètre dans lesquels on a planté des éclats de pommes de terre certifiées. Toutes les tiges sorties de terre étaient saines et le sont demeurées jusqu'à la fin. Les résultats négatifs que l'on a obtenus et rapportés il y a déjà quelques années (5) démontrent bien que le sol peut difficilement être considéré comme milieu favorable à la propagation de *C. sependonicum*. Nous pouvons conclure que, soit à cause des micro-organismes antagonistes ou autres raisons, la flétrissure ne se transmet pas par le sol dans la région du Bas Saint-Laurent.

Dans le Minnesota, des expériences ont démontré que l'organisme ne peut vivre longtemps dans un sol comme saprophyte, surtout lorsque la température et l'humidité favorisent la croissance d'autres saprophytes (11). Eddins (12) et Bonde (9) rapportent que la maladie ne se transmet pas par le sol dans les conditions où ils ont poursuivi leurs travaux. Tyner en Alberta (25) affirme que la maladie ne se transmet pas par le sol, après y avoir enfoui des débris de plantes malades. Larson en 1944 (15) a rapporté cependant que tous les plants de tomates repiqués dans un sol récemment contaminé avec une suspension de *C. sepedonicum* ont montré les symptômes de flétrissure. Depuis ces travaux, Perrault (19) a démontré la présence dans le sol de plusieurs micro-organismes antagonistes à *C. sepedonicum* et qui en empêchent la croissance. Certains de ces organismes produisent même la lyse de cet agent pathogène.

Dissémination par les contenants

En Floride (11), des expériences ont démontré que des sacs de jute contaminés peuvent disséminer la maladie. Des tubercules qui ont été laissés quelques heures dans ces sacs ont augmenté l'infection de 21 p. 100 dans le champ. Dans le Colorado (14) et le Minnesota (10), l'on a

démontré que les bactéries de la flétrissure sur des sacs de jute étaient encore virulentes après quatre mois. Dans le Wyoming, des sacs qui ont hiverné dehors, ont transmis la maladie à 45 p. 100 des tubercules (11). Ces derniers résultats confirment ceux déjà obtenus à Ottawa en 1939 (3).

A Sainte-Anne-de-la-Pocatière, on a utilisé des sacs de papiers dans lesquels on avait entreposé, durant l'hiver, des tubercules atteints de pourriture du cerne, pour transporter des pommes de terre coupées en morceaux pour la plantation. Celles-ci ont séjourné pendant un à trois jours dans les sacs avant d'être mises en terre. Lors de la récolte on a observé 6 p. 100 de flétrissure dans les rangs provenant de cette semence. Dans un autre essai, aux fins d'établir l'importance des contenants comme moyens de dissémination, on a utilisé des boîtes à claire-voie dans lesquelles on avait conservé des pommes de terre atteintes de pourriture du cerne durant l'hiver, pour recevoir les éclats de tubercules coupés quelques jours avant la plantation. On n'a pas observé de flétrissement avant la mi-septembre dans ces parcelles, mais au temps de la récolte, 1.2 p. 100 des buttes provenant de cette semence ont manifesté les symptômes de la pourriture du cerne.

Il est donc évident que la flétrissure bactérienne peut se transmettre à une semence saine, tout simplement par contact avec une surface contaminée et que, dans certains cas, l'agent pathogène est encore virulent après plusieurs mois d'exposition à des températures que l'on croirait lui être défavorables.

CONCLUSIONS

Les agents de dissémination de la pourriture du cerne tels qu'on les connait aujourd'hui et sur lesquels il n'y a plus de doute, sont tous sous le contrôle du cultivateur et la gravité de la maladie sur sa ferme dépend presque entièrement de ses connaissances et de sa bonne volonté. Il est incontestable que si la maladie n'existe pas déjà dans la semence, sa propagation est nulle ou à peu près et les instruments qui servent à la disséminer, tels que les couteaux, les planteuses et arracheuses mécaniques, les cribles ainsi que les divers contenants cessent de remplir le rôle néfaste qu'ils ont joué jusqu'ici.

Après la semence, le couteau est sans contredit le principal agent de dissémination. Cet instrument peut contaminer, à l'insu du cultivateur, un nombre considérable de tubercules proportionné au degré d'infection de la semence. Il en est ainsi des planteuses et arracheuses mécaniques. Dans le Minnesota, une récolte faite avec une arracheuse contaminée, ramassée dans des paniers contaminées et entreposée dans des sacs contaminés, a produit l'année suivante quelques plants malades de flétrissure (11). Connaissant la virulence de l'agent pathogène il est évident que les cribles, les sacs de jute, les boîtes, les entrepôts aussi bien que les véhicules de transport peuvent être autant d'agents de dissémination s'ils sont venus en contact avec des tubercules atteints de cette maladie.

On a vu que le sol n'est pas un milieu favorable à la survivance de *C. sepedonicum* et qu'il ne peut être considéré comme agent de dissémination de la maladie. Ce milieu pullule de micro-organismes qui, pour la plupart, entravent sa croissance par la sécrétion de substances qui lui sont toxiques.

Il est possible que les instruments utilisés pour les divers travaux de culture et les nombreux insectes qui envahissent les champs de pommes de terre soient responsables de l'apparition soudaine de la maladie dans certains cas, mais on n'a pas encore démontré de façon irréfutable le rôle qu'on est parfois porté à leur attribuer.

Il y a encore les tubercules oubliés dans le champ lors de la récolte. Bonde (9) a observé, en 1942, que des tubercules enfouis dans la terre, à l'automne, peuvent germer et produire des plants flétris l'année suivante et qu'une récolte peut être ainsi contaminée, si ces plants surgissent dans un champ de pommes de terre. La même observation a été faite à Ottawa en 1939 (3). La même année l'on constatait, dans une de nos expériences, la survie de *C. sepedonicum* dans des tubercules oubliés sur le sol l'automne précédent et en 1945 et 1946, on observait le même fait sur deux fermes du Bas Saint-Laurent. Il est évident que la pratique de planter des pommes de terre deux années de suite dans le même champ doit être déconseillée, surtout si la récolte est malade l'année précédente. Généralement, les tubercules laissés sur le champ sont détruits par les basses températures de nos hivers, mais il arrive très souvent que ces tubercules sont enfouis par les labours d'automne. Ils sont alors suffisamment protégés et leur faculté germinative n'est aucunement affectée.

RÉSUMÉ

Les résultats d'expériences poursuivies dans la province de Québec, depuis 1937, ont démontré que les principaux agents de dissémination de la pourriture du cerne sont, par ordre d'importance, les tubercules porteurs de germes utilisés comme semence, les couteaux, les planteuses et arracheuses mécaniques ainsi que les divers contenants. Les tubercules oubliés dans le champ, à l'automne, peuvent contaminer la récolte l'année suivante, si le même champ est remis en pommes de terre. On n'a pu démontrer que les insectes, communément observés sur les pommes de terre, transmettaient la maladie et il semble bien établi que le sol n'est pas un facteur que l'on puisse tenir responsable de sa propagation, d'une année à l'autre, sous les conditions climatiques de notre pays.

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M. Jean-Louis Tremblay de la faculté des Sciences, Université Laval et M. Edgar Chevrette de la faculté d'Agriculture, également de l'Université Laval, qui ont servi de conseillers dans l'interprétation des résultats de nos expériences ont droit à notre reconnaissance. Les cultivateurs et, plus particulièrement M. Georges Dubé du deuxième rang de Mont-Joli, qui ont généreusement mis à notre disposition le terrain nécessaire pour certaines expériences, voudront bien accepter le témoignage de notre gratitude.

ENGLISH SUMMARY

Since 1937, experimental results obtained in the Province of Quebec have shown that potato ring rot is disseminated mainly by infected tubers, knives, planting and digging machines and various containers. No definite evidence was obtained as to the propagation of the disease in the field through cultural methods. Volunteer plants may become a source of

infection when the same field is planted to potatoes for two consecutive years. A higher rate of infection resulted when small tubers were planted as compared with large tubers, but much less infection was obtained from planting small and whole tubers than from larger and cut tubers. Bacteria-like bodies resembling *Corynebacterium sepedonicum* were observed in a few types of insects commonly feeding upon potato plants affected with ring rot, but no evidence was obtained as to the transmissibility of the disease through such insects. Under climatic conditions of this Province ring rot is not transmitted through the soil.

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AN OCCURRENCE OF BROWN STEM ROT OF SOYBEANS IN ONTARIO[1]

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On September 12, 1947, during an examination of a stand of soybeans in test plots at the Western Ontario Agricultural Experiment Station, Ridgetown, Ontario, the attention of the writer was attracted to plants of the variety Lincoln, a few of which had lodged and many of which showed a more or less prominent brownish discoloration of the lower part of the stem. When cut open, stems of affected plants showed a browning and necrosis of the pith and xylem, that, starting at or just below the ground level, extended upwards for distances varying according to the stage of development of the disease. From observations made on the above-mentioned date and on two later occasions, September 17 and 25, it was noted that affected plants exhibited certain foliar symptoms, the prominence of which seemed to bear some relationship to the extent of spread of infection on or in the stem. For example, on plants that showed just the beginning of external discoloration, the only other evidence of the presence of the disease in several instances was a blighting of a few of the lower leaves. On other plants, however, in which external discoloration was more readily apparent and in which, too, internal discoloration and necrosis had progressed higher in the stem, leaves towards the tip showed interveinal chlorosis followed by necrosis, the final scorched appearance of the foliage suggesting frost injury. The latter could not have been a factor, however, since temperatures did not fall to freezing levels until September 26. On the many plants that had lodged by September 26, the foliage was for the most part dead and internal stem discoloration of the type shown in Figure 1 had extended to the tip region of the stems. These symptoms approximated so closely those described in 1946 by Allington (1, 2) for brown stem rot of soybeans that, for final verification of the identity of the disease, it seemed only necessary to isolate the causal organism.

Stems of a number of plants showing various stages of the disease were split open and small particles of discoloured tissue were transferred to poured plates of potato dextrose agar. Almost invariably, a slow-growing fungus with putty-coloured mycelium and a semi-appressed, actinomycete-like growth habit, developed from the tissue plantings. In the absence of fruiting bodies after several weeks' growth on the original plates and on potato dextrose agar slants, it was not possible to identify the organism on that medium, However, when the fungus was cultured on 2 per cent agar by employing an adaptation of a technique described by Vernon (8) in 1931, identification at least as to the genus was readily possible. The technique was as follows: A few drops of the medium

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were allowed to spread and cool on a sterilized slide. From the centre of the solidified agar, a small square was cut out and discarded. Then, a side-wall of the square opening in the medium was inoculated with a small particle of the fungus. The opening was then sealed by placing over it a sterilized cover slip that was gently adpressed to the surface of the surrounding medium. The opening, thus enclosed, constituted a miniature moist-chamber in which any development of the fungus could be closely observed. A number of slides prepared in this way were incubated at room temperature over moist blotting-paper in Petri plates.

Within three days conidiophores with attached conidia were observed and photographed. The non-septate, oval-shaped conidia (Figures 3, 4 and 5) are very small, none having been observed that exceeded $2.5\ \mu$ in width and $5.0\ \mu$ in length. They are abstricted from the tips of the conidiophores to which they adhere and form heads of irregular size and shape (Figures 2 and 3). The slender, usually unbranched conidiophores vary considerably in length.

In its morphology the fungus is characteristic of the genus *Cephalosporium*, as described by Buchanan (4). It is indistinguishable from the *Cephalosporium* species recently described by Presley and Allington (7) as the causal organism of brown stem rot of soybean.

According to Allington (1), the disease first appeared in a few fields in Central Illinois in 1944 and, in 1945, it occurred in severe epidemic form in Central Indiana, Illinois, and Iowa. In August, 1947, Cartter (5) warned that "brown stem rot is possibly the most threatening of any of the diseases that are now known to attack the soybean." The fungus exists in the soil and infection takes place either through the roots or at the base of the stem near the ground level. The incidence of the disease is considered to be dependent upon low air temperatures. Consequently, it may not be expected to appear until fall. There is no evidence to suggest that the disease is seed-borne. As yet, little is known about varietal resistance or susceptibility to the disease. At Ridgetown, it could not be found in plots of the varieties Capital, Richland, and Earlyana, contiguous to those of Lincoln. In September, 1947, Allison (3), in reviewing the present status of soybean diseases in the United States, commented in regard to brown stem rot that "continuous cropping with soybean favoured the development of the fungus and if such practice was broken by means of other crops in rotation the disease did not seriously attack soybeans when they were replanted on infected areas." In July, 1947, Hildebrand and Koch (6) described another disease occurring on soybeans in Ontario, viz., bud blight, which is also characterized by a reddish-brown discoloration of the internal tissues of the stem. In bud blight, however, this discoloration instead of starting at the base of the stem, as is the case with brown stem rot, appears first in the neighbourhood of the upper nodes of the plant and progresses downward.

FIGURE 1. Lower stem region of soybean plants affected with brown stem rot, showing discoloured and necrotic internal tissues.

Conidia and conidiophores of *Cephalosporium* sp. on soybean. FIGURE 2. General growth habit of the fungus. FIGURE 3. Individual conidiophore with adhering conidial head. FIGURES 4 and 5. Conidia. (All X400).

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SUNFLOWER SEED AND RAPE-SEED OIL MEALS IN CHICK STARTER RATIONS[1]

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Sunflower seed and rape-seed oil meals are now produced in Western Canada as by-products of the oil extraction process. Their use as protein supplements in commercial poultry rations has become general due to shortages of animal protein supplements. Information on their suitability for this purpose is limited.

Pettit *et al.* (1) used sunflower seed oil meal at levels ranging from 2 per cent to 14 per cent to replace partly or completely the 10.5 per cent meat meal in their basal chick starting rations. Weight and mortality at ten weeks showed no significant difference. When they used rape-seed oil meal in a similar experiment the growth rate was significantly retarded at the 17 per cent level, whereas at the 20 per cent level (which replaced all of the meat meal) growth was further reduced and mortality increased. All of the above mentioned chick rations contained 10 per cent buttermilk powder. The Nutrition Department at Macdonald College, Quebec (2), conducted feeding tests, using sunflower seed oil meal in combination with soybean meal, meat meal and dried buttermilk, which showed that the sunflower seed oil meal was an incomplete protein for chicks. These workers further state that "the most favourable combination was obtained where 2 per cent milk, 3 per cent meat meal and 6 per cent soybean meal were combined with 6 per cent sunflower seed meal."

MATERIALS AND METHODS

Chicks were reared in battery brooders until two weeks of age, then transferred to electric brooders on the floor. For the sunflower seed oil meal feeding trials, two lots of New Hampshire cockerels and two lots of cross bred (New Hampshire × Light Sussex) cockerels were used. There were sixty-two chicks in each group. Twenty-five chicks, picked at random from each lot, were weighed weekly. In the case of the rape-seed oil meal tests, four lots each of 75 White Leghorn unsexed chicks were used. Forty chicks picked at random from each lot were weighed weekly. In all feeding trials only chick starter and water were provided *ad lib.*

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TABLE 1.—BASAL CHICK STARTER RATION

Wheat chop	25 lb.	Cereal grass	2 lb.
Oat chop	15 "	Iodized salt	½ "
Oat groats	10 "	Fish oil (400D, 2400A)	¼ "
Barley chop	20 "	Manganese sulphate	6 grams
Bran	5 "	*Riboflavin premix	5 "
Alfalfa meal	5 "		
		Total	82¾ lb. 11 grams

*One gram of riboflavin per ounce of premix. The riboflavin premix was kindly supplied by Merck & Co., Ltd., Montreal, Que.

TABLE 2.—COMPOSITION OF RATIONS

Ration:	1	2	3	4	5
	lb.	lb.	lb.	lb.	lb.
Basal ration	82¾	82¾	82¾	82¾	82¾
Meat meal (55%)	7½	3¾	4	7½	7½
Fish meal (70%)	2	0	2	0	2
Skimmilk powder	2	0	2	2	0
Sunflower seed oil meal	2	10	0	0	0
Rape-seed oil meal	0	0	5	4	2
Bone meal	½	1½	1	½	½
Limestone powder	1	1¼	1¼	1¼	1¼
	97¾	99¼	98	98	96

TABLE 3.—CHEMICAL ANALYSIS OF OIL MEALS

	Protein	Fibre	Fat	Ca.	P.
Sunflower seed oil meal	40	9	7.0	0.48	0.93
Rape-seed oil meal	34	13	7.5	0.57	0.93

According to the calculated analysis the protein, calcium and phosphorus were maintained at approximately the same levels in all of the above rations. To maintain this balance adjustments in bone meal and limestone were made. All rations were calculated to conform to the nutritional requirements as set out by W. R. Ewing (3).

RESULTS

Sunflower Seed Oil Meal Feeding Trials

TABLE 4.—MEAN WEIGHTS AND MORTALITY

Rations:	1		2	
	Lot 1 (NH)	Lot 2 (XB)	Lot 3 (NH)	Lot 4 (XB)
Mean weights at 7 weeks	773.6 gm.	803.6 gm.	687.6 gm.	677.2 gm.
% Mortality	1.6 %	3.1 %	0 %	3.1 %

TABLE 5.—ANALYSIS OF VARIANCE OF 7-WEEK OLD WEIGHTS

	D.F.	Variance	F.	5% F.
Between rations	1	381,961.00	*28.84	3.94
Between breeds	1	2,401.00	0.24	
Interaction	1	10,201.00	1.04	
Error	96	9,776.68		
	99			

* Significant at 1% point.

Table 5 shows a significant difference in weights at 7 weeks of age between rations 1 and 2.

Rape-seed Oil Meal Feeding Trials

TABLE 6.—MEAN WEIGHTS AND MORTALITY

Rations:	1	3	4	5
	Lot 1	Lot 2	Lot 3	Lot 4
Mean weights at 7 weeks	405.0 gm.	405.25 gm.	414.0 gm.	395.75 gm.
% Mortality	17.0 %	16.2 %	15.6 %	13.5 %

TABLE 7.—ANALYSIS OF VARIANCE OF 7-WEEK OLD WEIGHTS

	D.F.	Variance	F.	5 % F.
Between rations	3	2755.0	0.522	2.67
Within rations (error)	156	5274.9		
	159			

Table 7 shows that differences in mean weights at 7 weeks of age between rations are not statistically significant. Above normal mortality in the rape-seed oil meal trials was due to accidental chilling at three weeks of age but the surviving chicks reached a normal average weight at seven weeks (4).

DISCUSSION

Results obtained indicate that sunflower seed oil meal when fed at 2 per cent level in combination with 7½ per cent meat meal, 2 per cent fish meal and 2 per cent skimmilk powder (ration 1) produced above normal rate of growth (4) to seven weeks of age (Table 4). When 10 per cent of this supplement was used in combination with 3¾ per cent meat meal, in the absence of fish meal and skimmilk powder, growth rate in chicks to seven weeks was decidedly slower than normal (4). These results differ from those obtained by Pettit *et al.* As all of their rations contained 10 per cent buttermilk powder, it was thought desirable to test the feeding value of sunflower seed oil meal in chick rations in the absence of skimmilk powder. Results obtained at Macdonald College (2), indicating that sunflower seed oil meal is an incomplete source of protein for growth, are further confirmed by our feeding trials. According to the above workers the most suitable combination included considerable soybean oil meal which was excluded from all rations used in our trials for the same reason as milk powder.

Rape-seed oil meal was satisfactory in replacing one-half of the meat meal (3¾ per cent), all of the fish meal (2 per cent) and all of the milk powder (2 per cent) in chick starter rations. These results agree with those obtained by Pettit *et al.* at lower levels of this supplement. Here again all their rations contained 10 per cent buttermilk powder. Complete exclusion of skimmilk powder from ration 5 resulted in slightly but consistently lower weight throughout the growing period but this difference was not statistically significant.

SUMMARY

1. Two per cent sunflower seed oil meal in chick rations when combined with $7\frac{1}{2}$ per cent meat meal, 2 per cent fish meal and 2 per cent skimmilk powder, produced normal growth in chicks up to seven weeks of age.

2. Ten per cent sunflower seed oil meal, when combined with $3\frac{3}{4}$ per cent meat meal in the absence of fish meal and skimmilk powder, resulted in decidedly slower than normal growth rate in chicks to seven weeks of age.

3. Rape-seed oil meal when used in chick starter rations, satisfactorily replaced one-half of the meat meal ($3\frac{1}{2}$ per cent), all of the fish meal (2 per cent) and all of the skimmilk powder (2 per cent).

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CHOLINE CONTENT OF LIVE STOCK FEEDS USED IN WESTERN CANADA[1]

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INTRODUCTION

Recognition of the importance of choline in a number of metabolic processes, and more specifically its relation to growth promotion and prevention of perosis or slipped tendon in poultry, has led to an increasing interest in the choline content of feeding stuffs used in compounding animal and poultry rations. Glick (4) has reported values for a number of samples of pure varieties of wheat, oats, barley, flax and soybeans, while Engel (2), and Rhian, Evans and St. John (5) have surveyed the choline content of a variety of feeding stuffs available in the United States. The results of choline assays conducted on plant and animal by-products commonly used in live stock and poultry feeds in Western Canada and on grains and roughages grown in the Province of Alberta in 1944 and 1945 are reported in the present paper.

EXPERIMENTAL

Assay Material

Grains

Most of the grains assayed were obtained from University of Alberta test plots and from Dominion Illustration and Experimental Stations located in the gray, black and brown soil zones of the Province of Alberta. Samples were chosen to represent a wide range in protein content. An attempt was made to limit selections to Marquis wheat, Victory oats and Newal barley, but in order to obtain greater numbers in certain protein ranges it was necessary to include a few samples of other varieties.

Roughages

The limited number of roughage samples assayed were selected primarily to provide comparisons between legume and grass hays and between hays of good and poor quality. Leafy, green samples were graded "good", while samples which appeared to have been over-ripe when cut or had been weathered in curing were graded "poor" in quality.

Manufactured Feeds and By-products

A number of commercial poultry feeds together with samples of plant and animal by-products commonly used by the feed trade in Western Canada were furnished through the co-operation of feed manufacturers and processors in Edmonton, Calgary, Medicine Hat and Winnipeg.

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[2] Part of the data presented here are taken from a thesis submitted by Hugh A. Rigney in partial fulfilment of the requirements for the degree of Master of Science.

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Assay Procedure

Feeds were ground through the 0.5 mm. screen of a Wiley mill and duplicate air-dry samples estimated to contain the equivalent of 4 to 8 milligrams of choline chloride were weighed and transferred to alundum thimbles of medium porosity for extraction. The procedure outlined by Glick (3) was followed to obtain a solution of extracted choline reineckate[1] in acetone. The acetone solution of choline reineckate was transferred quantitatively with acetone washings and made up to volume in a 25 ml. glass stoppered volumetric flask. Readings to determine the concentration of choline reineckate in the solution were made with an Evelyn photoelectric colorimeter, using filter No. 515. Final calculations, expressed as milligrams of choline chloride per gram of sample, were made with the aid of reference to a standard curve of "L values" drawn from readings obtained with solutions of known choline chloride concentration. Periodic recovery trials indicated recoveries of from 92 to 103 per cent of choline chloride added to grain samples.

RESULTS AND DISCUSSION

A summary of the results is shown in Table 1. The samples of wheat, oats and barley assayed for choline were grown under diverse conditions of soil and climate and varied in protein content from a minimum of 8.2 per cent to a maximum of 19.8 per cent, basis 13.5 per cent moisture. Analysis of the results did not demonstrate the existence of any relationship between the choline content of these grains and the region in which they were grown. Similarly there was no relationship between choline and protein levels in these samples. Since samples selected for assay were, in so far as possible, limited to the varieties Marquis, Victory and Newal for wheat, oats and barley, respectively, too few values were obtained for other varieties to make reliable comparisons of choline levels in different varieties of one species; but it may be recorded that the limited number of such comparisons that could be made did not suggest the existence of significant varietal differences in the choline content of these grains. Thus, in the final summary (Table 1) the results for all samples of each grain were grouped without regard to protein content, origin, or variety.

It is shown in Table 1 that the mean choline value derived for wheat was approximately 15 per cent lower than that obtained for oats or barley. Statistical analysis of the data showed that the differences of 0.13 and 0.15 milligrams per gram between the means for oats and wheat, and barley and wheat, respectively are highly significant.

The number of hay samples assayed was limited and more difficulty was experienced in obtaining reproducible assay values for hays than for grains. With these points in mind the following observations may be made with reference to the results for hays listed in Table 1: (*a*) legume hays appear to be better sources of choline than are grass hays, and (*b*) legume or grass hays that have been improperly cured or made from over-ripe plants may be expected to contain appreciably less choline than well cured hays harvested at the right stage of maturity.

[1] Reinecke salt was made in the laboratory according to the method of Block and Bolling (1). Fresh methanol solutions were prepared at least once weekly and were stored in a refrigerator. Samples of commercial Reinecke salt were found to give highly variable results.

The assay values obtained for choline in plant and animal by-products in the present study are in reasonably good agreement with values for similar products reported by Engel (2), and are considerably higher than

TABLE 1.—CHOLINE CONTENT OF GRAINS, ROUGHAGES, PLANT AND ANIMAL BY-PRODUCTS AND COMMERCIAL FEEDS

Product	No. samples	Choline range	Chloride mean
		milligrams per gram*	
Grain:			
Wheat	23	0.84–1.14	0.95
Oats	25	0.94–1.30	1.08
Barley	32	0.86–1.46	1.10
Flax	2*	1.04–1.13	1.08
Yellow corn	1	— —	0.43
Hay:			
Alfalfa, good quality	3	1.38–1.98	1.71
Alfalfa, poor quality	3	1.07–1.44	1.31
Altaswede clover, good quality	1	— —	1.36
Yellow sweet clover, good quality	1	— —	1.11
Bromegrass, good quality	2	0.56–0.66	0.61
Bromegrass, poor quality	2	0.33–0.39	0.36
Timothy, good quality	1	— —	0.73
Crested wheat grass, good quality	1	— —	0.54
Oat silage, good quality	1	— —	0.88
Oat straw, good quality	1	— —	0.21
By-products:			
Wheat bran	2	1.43–1.48	1.46
Wheat shorts	2	1.54–1.58	1.56
Wheat middlings	2	1.20–1.44	1.32
Feeding wheat germ	3	2.56–2.60	2.58
Wheat germ	1	— —	3.25
Linseed oil meal	4	1.29–1.68	1.49
Soybean oil meal	5	2.70–3.15	2.49
Sunflower seed oil meal	1	— —	4.27
Meat meal	6	1.83–2.88	2.42
Tankage, wet rendered	2	1.48–1.70	1.59
Pork cracklings	1	— —	2.19
Fish meal	10	3.42–5.23	4.45
Blood meal	2	0.43–0.91	0.68
Skimmilk powder	7	1.56–1.86	1.70
Buttermilk powder	8	2.09–2.59	2.31
Whey powder	3	2.13–2.36	2.23
Miscellaneous:			
Brewer's yeast	1	— —	3.56
Dried cereal grass	2	1.05–1.06	1.06
Sunflower seed	1	— —	1.20
Commercial feeds:			
Chick starter	2	1.19–1.39	1.29
Growing mash	2	1.20–1.24	1.22
Laying mash	2	1.14–1.31	1.22
Laying supplement	1	— —	1.64
Hatching mash	2	1.49–1.50	1.50
Hatching supplement	1	— —	2.15
Turkey starter**	4	1.42–1.82	1.65
Turkey grower	1	— —	1.31

* Moisture-free basis for wheat, oats and barley; air-dry basis for all other samples.
** Three of these turkey starters are known to have been fortified with choline chloride.

those obtained by Rhian, Evans and St. John (5) by a method involving extraction with a mixture of ethyl alcohol and ether.

It is interesting to note that the mean values obtained for choline in buttermilk and whey powders are about 30 per cent higher than that for skimmilk powder. Buttermilk powder is essentially the dried skimmilk residue from the churning process, but during churning the enveloping lecithin layer of the fat globules is destabilized and freed to the residue. This may account partially for the relatively high concentration of choline in buttermilk powder. Similarly, in the process of cheese manufacture destabilized lecithin from the fat globules in milk may be released to the whey.

Since the choline content of mixed feeds is sometimes estimated by calculation from published data for choline levels in individual ingredients corresponding to those used in formulating these feeds, the following comparisons may be of interest. A sample of a turkey starter (not fortified with choline chloride) prepared by the University of Alberta Poultry Division was found by assay to contain the equivalent of 1.47 milligrams of choline chloride per gram. The estimated choline chloride equivalent, as derived by calculation from mean values listed in Table 1 for ingredients similar to those used in compounding this ration, was 1.59 milligrams per gram. Estimates of 1.30 and 1.87 milligrams per gram resulted when corresponding minimum and maximum values, respectively, from Table 1 were used to make the calculations.

SUMMARY

Choline assays were conducted on a number of live stock and poultry feeds.

The mean values obtained for choline in oats and barley were approximately 15 per cent higher than the mean for wheat. No evidence was derived to indicate the existence of a relationship between choline and protein levels in grains or between the choline content of grains and the soil zone in which they were grown.

Legume hays were found to be better sources of choline than grass hays. For a given kind of hay, samples of good quality, as measured by colour and leafiness, contained more choline than samples of poor quality.

The results of choline assays done on a number of by-product feeds and commercial mixed feeds are recorded.

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BOOK REVIEW

The Fruit and the Soil. Collected Edition of the John Innes Leaflets. Edited by Cyril D. Darlington. Oliver and Boyd, Edinburgh.

This collected edition of John Innes Leaflets deals with such subjects as composts and soil sterilization for pot plants; the fertility rules in fruit planting; growing tomatoes out-of-doors, and growing pure seed.

Standardized formulae of composts for specific crops and purposes are given. While some of the ingredients may not be easily available in this country the principle of standardizing composts commends itself. Varieties of cherries, plums and apples are listed according to their chromosome numbers and the question of inter-varietal compatability is discussed from the standpoint of pollination. While this type of information is of great practical value a large number of the varieties listed are not grown in this country. The section on tomatoes would be of little benefit to Canadian growers since the methods advised are largely regulated by very different climatic conditions. The section on growing pure seed contains much useful information that could be applied under Canadian conditions. This booklet contains valuable practical information for the English grower, gardener and seedsman but a considerable portion of the information is not applicable to Canadian conditions.

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